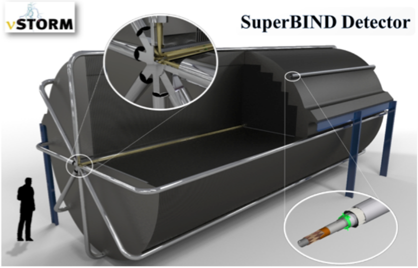
Magnetized Iron Neutrino Detectors (MIND) at LBNO & Baby-MIND

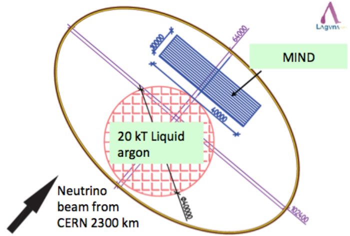
Etam NOAH - UNIGE

July 10, 2014

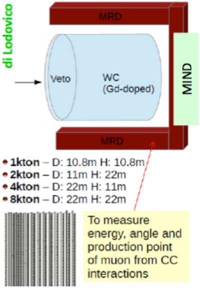
Future neutrino detectors with MINDs



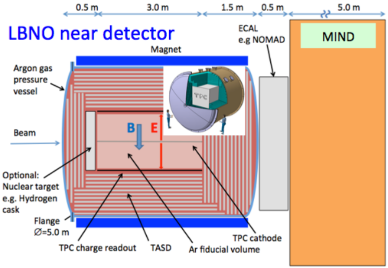
LBNO far detector



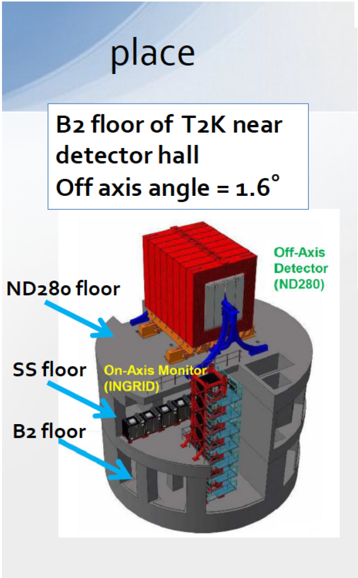
Hyper-Kamiokande near detector

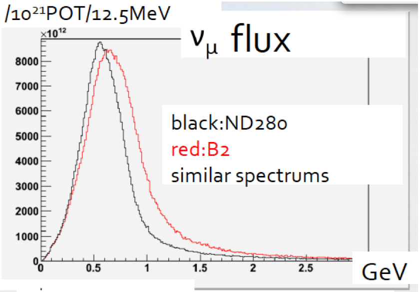


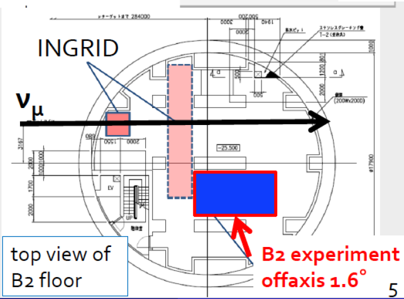
LBNO near detector



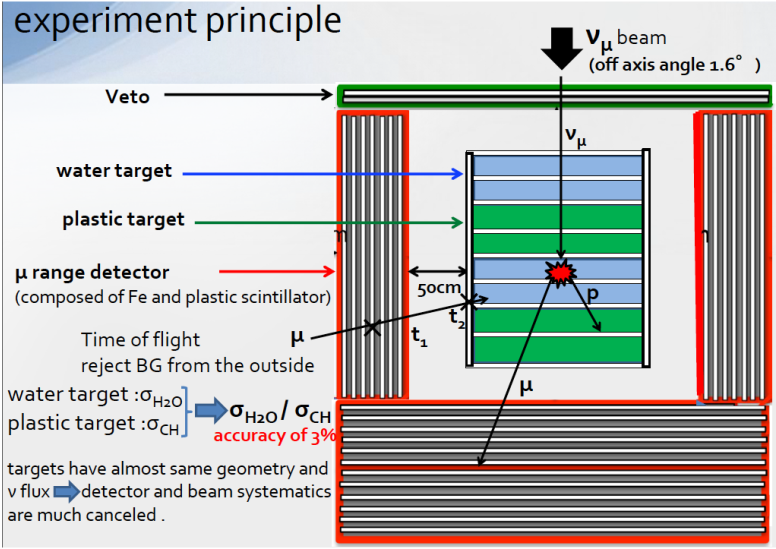
The B2 experiment: water ν σ measurements



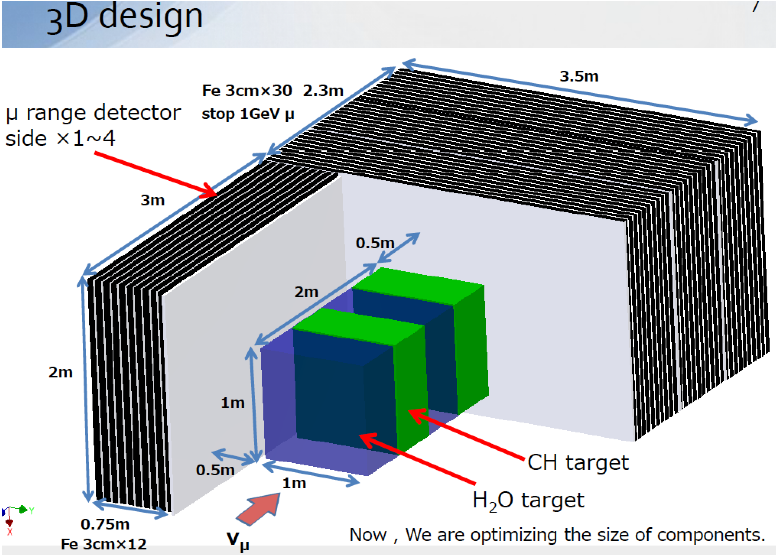




The B2 experiment



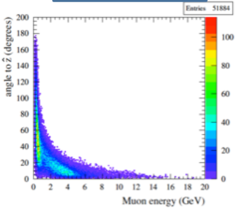
The B2 experiment



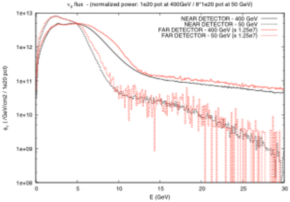
Energy range of neutrino beams

- Although energy range at future neutrino beam facilities can extend to tens of GeV, area of interest is < 10 GeV:
  - e.g. LBNO: first and second maxima, $3 < E_\nu < 6$ GeV and $1.2 < E_\nu < 1.8$ GeV;

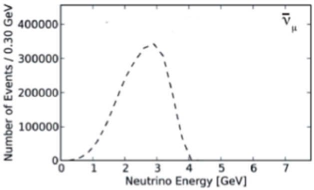
Hyper-K near detector: ν_μ flux exiting W-Ckov

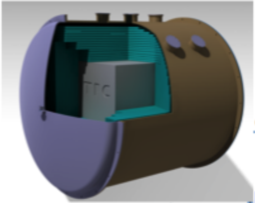


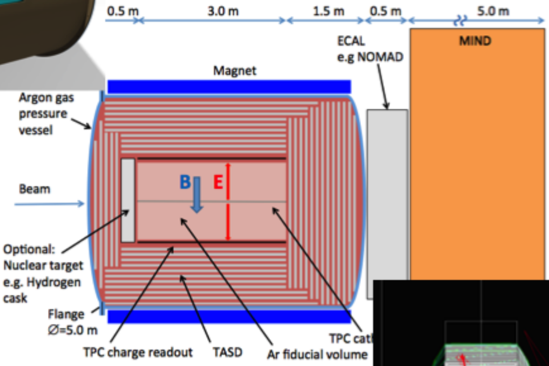
LBNO

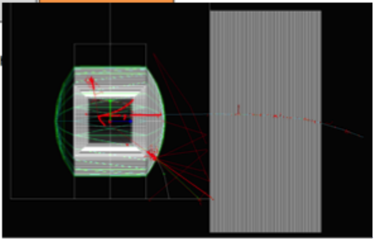


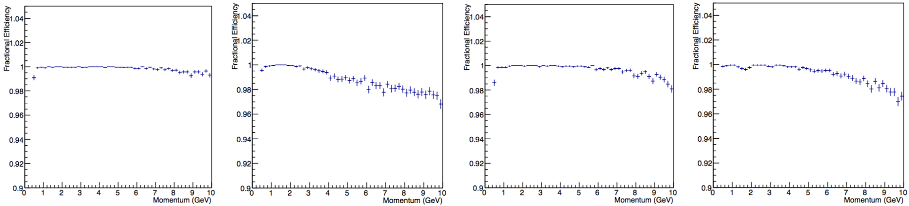
nuSTORM



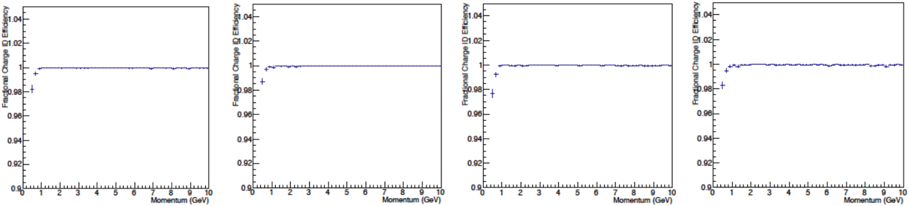



0.5 m
3.0 m
1.5 m
0.5 m
5.0 m
ECAL
e.g NOMAD
MIND
Magnet
Argon gas
pressure
vessel
Beam
B
E
Optional:
Nuclear target
e.g. Hydrogen
cask
Flange
Ø=5.0 m
TPC charge readout
TASD
Ar fiducial volume

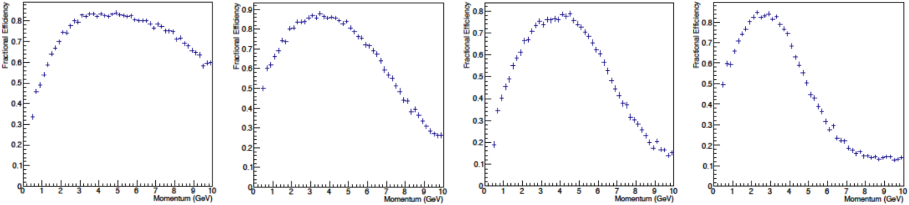




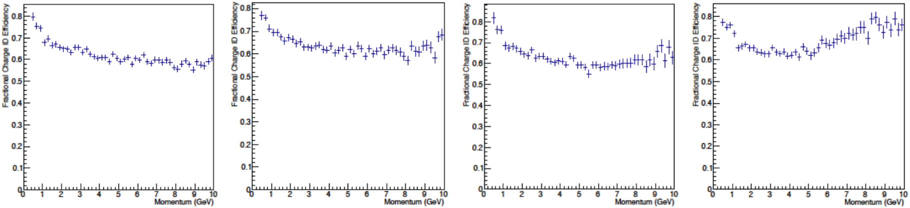
Reconstruction efficiencies for μ^+, from left: a) 3 cm steel, 1.5 cm scintillator. b) 2 cm/1.5 cm. c) 3 cm/3.5 cm. d) 2 cm/3.5 cm.



Corresponding charge identification efficiencies for μ^+.



Reconstruction efficiencies for π^+, from left: a) 3 cm steel, 1.5 cm scintillator. b) 2 cm/1.5 cm. c) 3 cm/3.5 cm. d) 2 cm/3.5 cm.

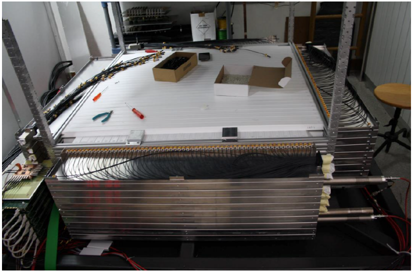


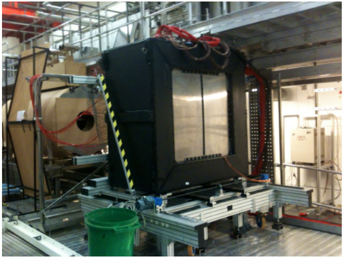
Corresponding charge identification efficiencies for π^+.

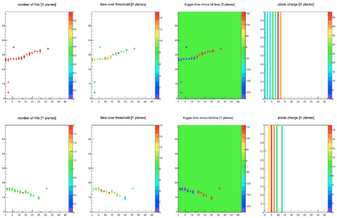
MIND (& TASD) prototyping

- Totally Active Scintillating Detector (TASD):
  - Stopping properties of π and μ (MICE EMR at RAL);
  - e and μ charge separation inside a B field, in particular e charge ID in ν_e interactions for the platinum channel at a NF: 0.5 - 5 GeV/c (MORPURGO).
- MIND:
  - μ charge ID, for wrong sign μ signature of a ν oscillation event: golden channel at νSTORM, NF: requires correct sign background rejection of 1 in 10^4: test beam 0.8 to 5 GeV/c (babyMIND);
  - Hadronic shower reconstruction for identification of charged current ν interactions and rejection of neutral current ν interactions: test beam p/π 0.5 to 9 GeV/c (babyMIND).
- Technology:
  - Better computing and new software tools are leading to better capabilities for event reconstruction BUT... Need test beam data to benchmark new reconstruction techniques;
  - Improvements in components (e.g. photosensors, electronics);
  - Review and update costing models for planned large detectors.

MICE Electron Muon Ranger (EMR)

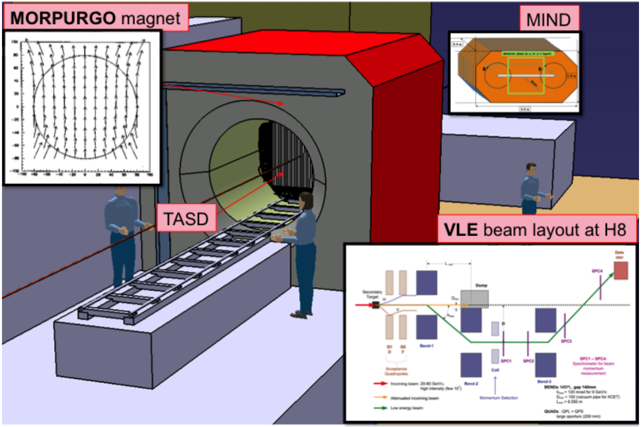




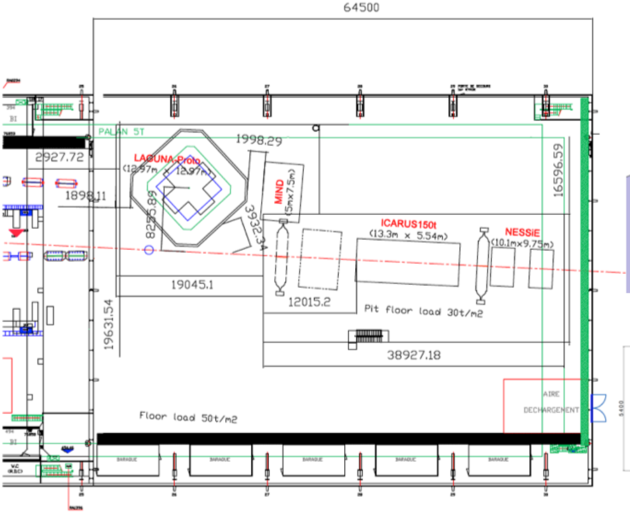


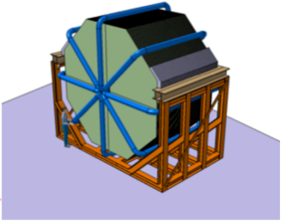
MIND and TASD: H8 beamline in North Area

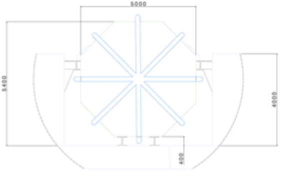
- Beam tests 2015;
- Requires beamline (studied by AIDA WP8.2.1).



MIND downstream of LAr at EHN1: option in WA105

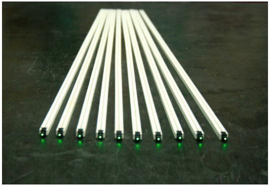


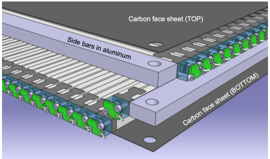


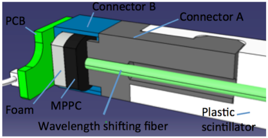


Detector modules

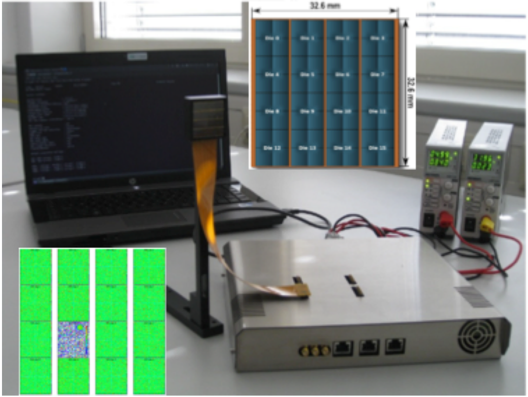
- Extruded scintillator slabs produced at Uniplast company, Vladimir, Russia:
  - polysterene-based, 1.5% paraterphenyl (PTP) and 0.01% POPOP.
  - Dimensions: $900 \times 10 \times 7$ mm^3
- Slabs are etched with a chemical agent (Uniplast) to create a 30-100 μm layer that acts as a diffusive reflector;
- WLS fiber embedded in 2 mm-deep groove along length of plastic slab and threaded through custom connectors either end;
- Of 10000 required bars, 3000 are produced.

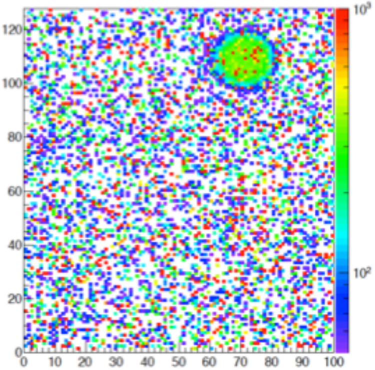






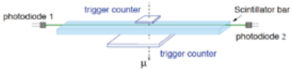
- Philips digital SiPM in dark count mode;
- 64 pixels (16 $\times$ 4), 3000 cells/pixel, cell size: 59.4 $\times$ 64 μm;
- Area within blue ring: 1.27 $\times$ 1.22 mm;
- Area with "high intensity": 1.00 $\times$ 1.02 mm.

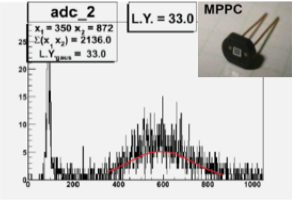




Plastic scintillator cosmic tests

- Tests carried out to determine basic light yield and timing properties;
- Light collection: Kuraray wavelength shifting fiber, 1.0 mm diameter, ∼1 m long, embedded in groove with Toshiba TSF451-50M silicon grease;
- Light readout: Hammamatsu MPPC (T2K) on both sides;
- Cosmic telescope:
  - two trigger counters;
  - upper one: $7 \times 7\ cm^2$ (L.Y.) and $2 \times 2\ cm^2$ (timing);
  - lower one: $10 \times 24\ cm^2$.
  - measurement at counter center: light yield per MIP.





	MPPC
Number of pixels	667
Active area	1.3×1.3 mm^2
Pixel size	50×50 μm^2
Gain	0.7×10^6
PDE at 525 nm	30-35%
Dark rate, thr = 0.5 p.e.,22C	<500 kHz
Pulse width	<100 ns
Cross-talk	10-20%
After pulses	10-20%
Sensitivity to magnetic field	no

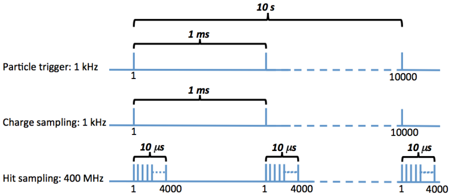
Light yield: slabs with chemical reflector

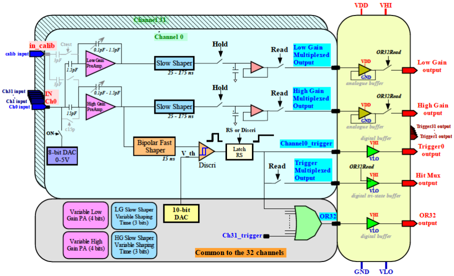
Slab width [mm]	**MPPC 1 L.Y.** [p.e.]	**MPPC 2 L.Y.** [p.e.]	$\Sigma_{L.Y.}$ **[1+2]** [p.e.]
Chemical reflector			
10	46.0	36.8	82.8
20	39.7	35.7	75.4
20	32.6	28.2	60.8
30	31.2	26.6	57.8
Chemical reflector, w/o optical grease			
20 - grease	25.7	22.1	47.8
Chemical reflector + Tyvek paper reflector			
20 + Tyvek	49.3	44	93.3

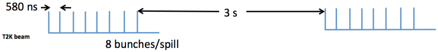
- $\sim \times$ 2.5 effect of chemical reflector;
- $\sim$ 60 % effect of optical grease;
- $\sim$ 20 % effect of additional Tyvek reflector.

Parameter	Unit	MPPC-T2K	ASD-40	KETEK	SensL
Manufacturer reported specifications					
Pixel size	μm	50	40	50	20
# of pixels		667	600	400	848
Sensitive area	mm^2	1.3×1.3	dia 1.2	1.0×1.0	1.0×1.0
Gain		7.5×10^5	1.6×10^6	-	-
Dark rate	MHz	≤ 1	~ 3	≤ 2	≤ 2
Bias voltage	V	~ 70	30-50	33-50	30
Measured performance					
Overvoltage	V	$\sim$1.4	3.6	4.5	2.7
Dark rate	kHz	900	3630	1250	1960
Crosstalk	%	10	13.4	35	9.7
Pulse shape	-	good	good	long tails	good
Peak separation	-	good	good	bad	bad
PDE	%	25.6	11	26.4	14.2

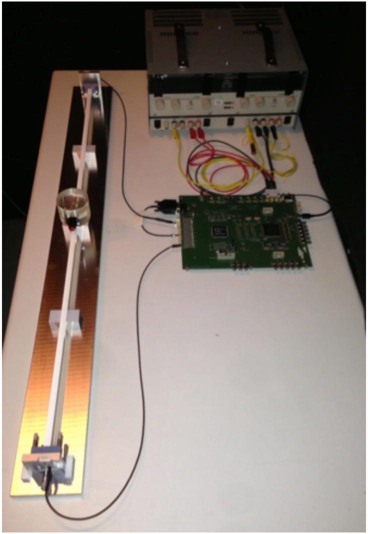
Easiroc schematic and planned charge+hit measurements

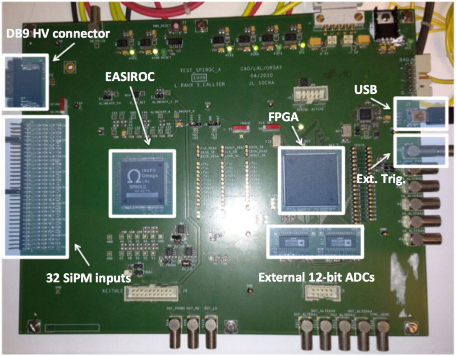




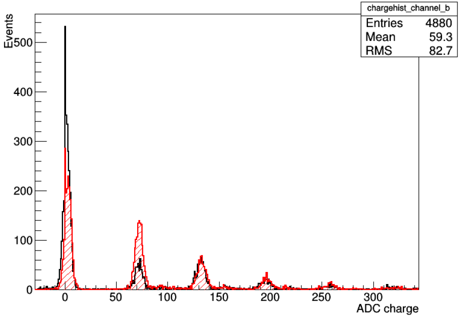


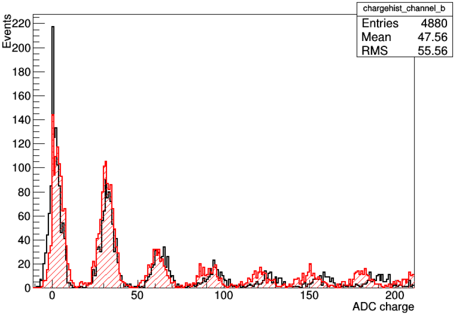
Easiroc evaluation setup





Easiroc tests with latest generation MPPC

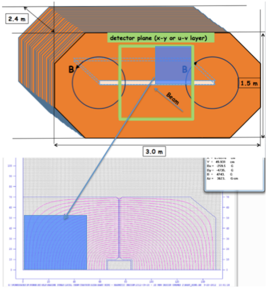


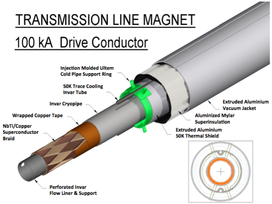


Charge spectra for the MPPC S12571-050C, a 50-micron cell size, 1×1 mm^2 device. Analogue data from the high gain signal path from the EASIROC chip, digitised with a 12-bit ADC, demonstrates the excellent photo-electron peak-to-peak separation. The EASIROC pre-amp feedback capacitance is set to 100fF, the shaper τ is set to 50ns. Left) high over voltage leading to $\sim$ 65 ADC/p.e. Right) low over voltage leading to $\sim$ 30 ADC/p.e. ΔV between left and right acquisitions is 1.75 V.

Magnetization studies

- Measuring B-field in-situ:
  - Slit in steel, few mm...
  - fill with non-magnetic material (e.g. SS316L);
  - Insert probe to measure field at various points along slit;
  - Small distortion of field lines;
  - Measurements validate simulated field across whole detector;
  - 23000 At with slot c.f. 4000 At without slot.
- Superconducting option:
  - Superconducting Transmission Line studied for VLHC.





Summary

- Several future facilities plan MIND-type detectors:
  - Near term: how can we contribute to the B2 experiment?
- Progress in software reconstruction and analysis:
  - These are being applied e.g. to νSTORM analyses;
  - Benchmark against test beam data on hardware that is well characterized.
- Detector module R&D:
  - High light yields are being reached with combination of plastic scintillators and latest generation photosensors;
  - We are developing readout electronics based on the EASIROC chip.
- We plan beam tests of MIND-type detectors in the near term 2015-2020:
  - Baby-MIND at the H8 beamline in the North Area at CERN;
  - Potential for WA105-MIND at the new EHN1 facility in combination with LAr.